higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

POWER MACHINES N5

(8190035)

21 April 2021 (X-paper)
09:00–12:00

REQUIREMENTS: **Properties of water and steam (BOE 173)**
Superheated steam tables (appendix to BOE 173)

Nonprogrammable calculators may be used.

This question paper consists of 6 pages and a formula sheet of 3 pages.

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NATIONAL CERTIFICATE
POWER MACHINES N5
TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer all the questions.
2. Read all the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. Start each section on a new page.
5. Use only a black or blue pen.
6. Write neatly and legibly.

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QUESTION 1

1.1 Draw and label a graph of pressure versus volume to illustrate polytrophic expansion. (3)

1.2 State the second law of thermodynamics. (2)

1.3 Complete the following sentence by filling in the missing word or words. Write only the word or words next to the question number (1.3.1–1.3.2) in the ANSWER BOOK.

A governor is isochronous if the equilibrium (1.3.1) … is (1.3.2) ... for all radii of rotation. (2 × 1) (2)

1.4 Various options are given as possible answers to the following questions. Choose the correct answer and write only the letter (A–D) next to the question number (1.4.1–1.4.3) in the ANSWER BOOK.

1.4.1 Atmospheric air contains approximately … and … by volume.

A 79% N_2 and 21% O_2
B 77% N_2 and 23% O_2
C 23% N_2 and 77% O_2
D 21% N_2 and 79% O_2

1.4.2 The saturation temperature of the steam at 2 500 kPa is … .

A 240 °C
B 25 °C
C 223,9 °C
D 92 °C

1.4.3 Governors may broadly be classified as … .

A centrifugal and inertia
B separating and throttling
C economiser and evaporator
D condenser and air pump

(3 × 1) (3)
[10]

QUESTION 2

A gas at 22 °C is compressed isothermally from a pressure of 120 kPa and a volume of 4,2 m^3. The volume ratio of original volume to final volume is 3:1. Take R as 0,288 kJ/kg.K and C_V as 0,712 kJ/kg.K.

Determine:

2.1 Final volume in m^3. (3)

2.2 Mass of a gas in kg. (3)

2.3 Final pressure in kPa. (3)

2.4 Work done in kJ. (3)

2.5 Change in internal energy in kJ. (2)

2.6 Amount of heat absorbed or emitted in kJ. (2)

2.7 The change in entropy in kJ/K. (4)

[20]

QUESTION 3

FIGURE 1 shows that feed water enters an economiser at a temperature of 26,7 °C and leaves at 47,7 °C. The exit steam at the evaporator is 92% dry. The steam leaves the superheater at a pressure of 1,5 MPa and a temperature of 200 °C. Mass of steam is 2 500 kilogram per hour. Mass of coal is 200 kg per hour and the calorific value is 35 MJ/kg.

Determine the following:

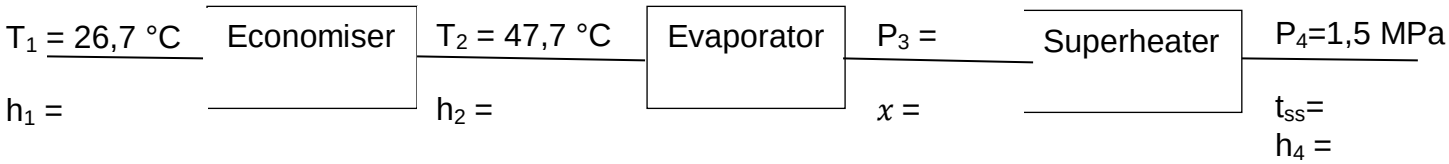

FIGURE 1

3.1 Complete the missing values in FIGURE 1, that is, the dryness fraction x, P_3 in kPa, t_{ss} and determine h_1, h_2, and h_4 with aid of the steam table. (6)

3.2 Mass of steam per kg of fuel burnt. (1)

3.3 Heat transferred to the economiser in kJ per kg of fuel burnt. (2)

3.4 Specific enthalpy of wet steam h_3 and the heat transferred to the evaporator in kJ per kg of fuel burnt. (5)

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3.5 Heat transferred to the superheater in kJ per kg of fuel burnt. (2)

3.6 Efficiency of the plant. (4)
[20]

QUESTION 4

4.1 100 kg steam with a dryness fraction of 0,75 enters a surface condenser per hour. The pressure is 10 kPa. Mass of cooling water is 1 850 kilogram per hour and the inlet temperature is 22 °C. The condensate temperature and the air pump suction temperature is 43,8 °C each. Use $C_{p\ water}$ = 4,187 kJ/kg.K

Calculate the outlet temperature of the cooling water. (6)

4.2 A gaseous fuel has the following volumetric analysis:

CH_4 = 32%
H_2 = 40%
CO = 20%
N_2 = 8%

For 1 m^3 of fuel, determine:

4.2.1 Balanced chemical equation of the combustion reaction of each fuel, that is, CH_4; H_2 and CO. (3)

4.2.2 Total volume of oxygen consumed in combustion as oxygen reacts with each fuel in QUESTION 4.2.1. (4)

4.2.3 The volume for each product of combustion of the gaseous fuel. (5)

4.2.4 Percentages of all products of combustion. (2)
[20]

QUESTION 5

A single cylinder, single acting reciprocal air compressor takes in air 2 m^3 of air per minute at 102 kPa. Air is delivered at 780 kPa and the compressor runs at 300 revolutions per minute. The free volume is 3% of the stroke volume. Index of compression n= 1,35

Determine:

5.1 Stroke volume in m^3. (9)

5.2 Power in kW. (3)

5.3 Work done in kJ. (3)
[15]

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QUESTION 6

An impulse turbine has a mean blade speed of 300 m/s. The speed of the turbine wheel is 230 r/min. The nozzle angle is 20° and the gas leaves the nozzles at a velocity of 800 m/s with a mass of 2 kilograms per second. The blade outlet angle is 20° and the coefficient of friction is 0,75.

6.1 Construct a velocity diagram on LANDSCAPE FORMAT. Label all the angles and the velocity values in m/s. Use a scale of 1 cm = 50 m/s. (10)

6.2 From the diagram, determine:

6.2.1 The moving blade inlet angle. (1)

6.2.2 The angle exiting the turbine. (1)

6.2.3 The power generated by the turbine in kW. (3)

[15]

TOTAL: 100

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POWER MACHINES N5

FORMULA SHEET

1. $Q = W + \Delta U$
2. $\Delta U = mC_{\upsilon}\Delta T$
3. $Q = mC_{\upsilon}\Delta T$
4. $Q = mC_{p}\Delta T$
5. $Q = P_1V_1 \ln \frac{V_2}{V_1}$
6. $\Delta S = m\left(C_{\upsilon} \ln \frac{T_2}{T_1} + R \ln \frac{V_2}{V_1} \right)$
7. $W = P_1\Delta V$
8. $W = P_1V_1 \ln \frac{V_2}{V_1}$
9. $W = \frac{P_1V_1 - P_2V_2}{n-1}$
10. $W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$
11. $R = C_p - C_{\upsilon}$
12. $\gamma = \frac{C_p}{C_{\upsilon}}$
13. $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
14. $PV = mRT$
15. $P_1V_1 = P_2V_2$
16. $P_1V_1^n = P_2V_2^n$
17. $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = \left(\frac{V_1}{V_2}\right)^{n-1}$
18. $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$
19. $h = h_f + \chi h_{fg}$
20. $h = h_g + C_p\Delta T$
21. $h = h_f + h_{fg} = h_g$
22. $V_{\text{sup}} = \frac{n-1}{n}\left(\frac{h_{\text{sup}} - 1\,941}{P}\right)$
23. $\chi = \frac{V_m}{V_g}$
24. $\chi = \frac{M}{M + m}$
25. $U = H - PV$
26. $gZ_1 + U_1 + P_1V_1 + \frac{1}{2}C_1^2 + Q =$

    $gZ_2 + U_2 + P_2V_2 + \frac{1}{2}C_2{}^2 + W$
27. $\eta = \frac{\dot{m}_s(h_2 - h_1)}{\dot{m}_f\, CV}$
28. $EE = \frac{\dot{m}_s(h_2 - h_1)}{\dot{m}_f\ 2\,257}$
29. $p = (B_m \pm M_m)\frac{101{,}325}{760}$

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30. $$m = \frac{100}{23}\left[C\frac{8}{3} + 8H_2 + S - O_2\right]$$

31. $$C_xH_y + \left(x + \frac{y}{4}\right)O_2 = xCO_2 + \frac{y}{2}H_2O$$

32. $$H.C.V. = (CV_C.C) + CV_{H_2}\left(H_2 - \frac{O_2}{8}\right) + (CV_s.S)$$

33. $$L.C.V. = H.C.V. - h_{fg}\,(9H_2)$$

34. $$H.C.V. = \frac{(m_w + m_e)\,C_p\Delta T}{m_f}$$

35. $$W = P_1V_e\left(\frac{n}{n-1}\right)\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right] = mRT_1\left(\frac{n}{n-1}\right)\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

36. $$\eta_c = \frac{V_e}{V_s}.100 = 1 - \frac{Vc}{Vs}\left[\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} - 1\right] = 1 + \alpha - \alpha(r_p)^{\frac{1}{n}}$$

37. $$\eta_\alpha = \frac{V_\alpha}{V_s}.100$$

38. $$F_c = \dot{m}(C_{fe} - C_{fi})$$

39. $$P = \dot{m}U[C_{wi} - (-C_{we})]$$

40. $$\eta = \frac{2U[C_{wi} - (-C_{we})]}{C_{ai}{}^2}.100$$

41. $$U = \pi DN$$

42. $$\dot{m}V = AC$$

43. $$(m + M)\,g = m\omega^2 h$$

44. $$Vs = \frac{\pi}{4}D^2L$$

45. $$\theta_1 = t_c - twi$$

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46. $\theta_2 = t_c - two$

47. $$Log.temp.diff. = \frac{\theta_1 - \theta_2}{\ell n \frac{\theta_1}{\theta_2}}$$

48. $$Piso = P_1 V_1 \ell n \left(\frac{P_2}{P_1} \right)$$

49. $$Pact = \frac{n}{n-1} P_1 V_1 \left[\left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right]$$

50. $$Niso = \frac{Piso}{Pact} \bullet 100$$

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